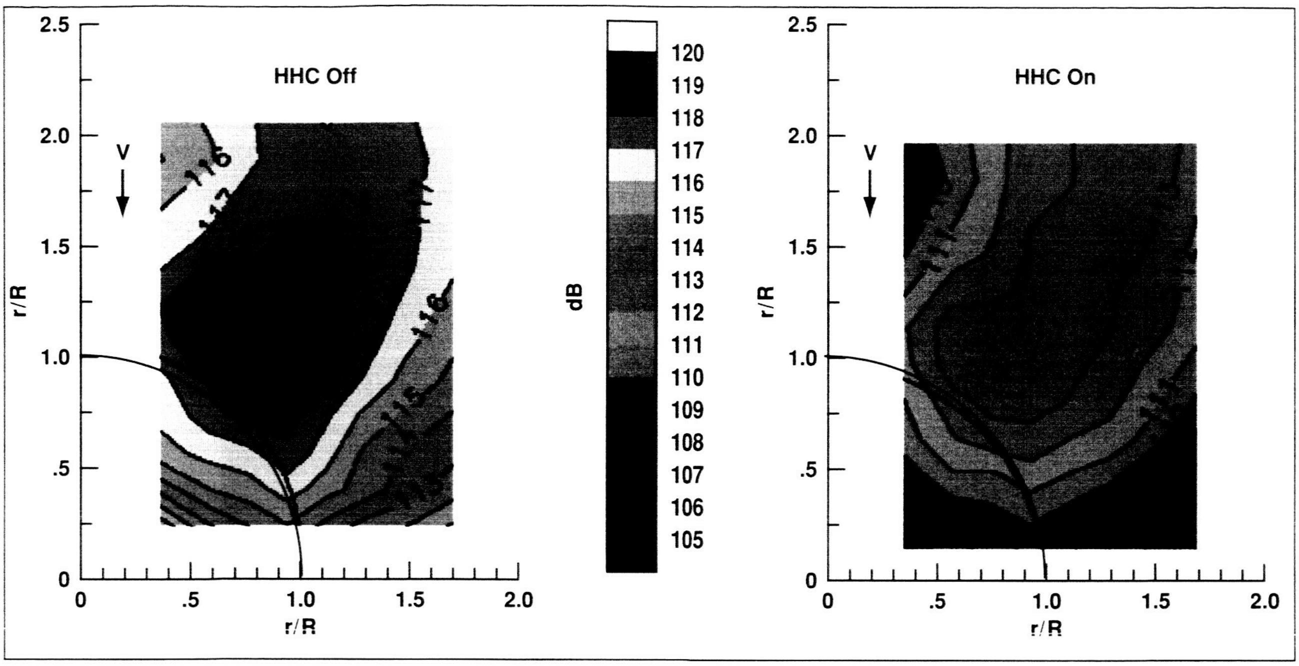

Fig. 1. Noise controller reduces noise measured on a plane under the XV-15 rotor: tunnel speed 69 knots, rotor thrust 5,500 pounds.

Tilt-Rotor Noise Reduction Study

Thomas R. Norman

The successful introduction of the civil tilt rotor into the national airspace system relies heavily on its community acceptance. In particular, a tilt rotor with reduced noise emissions is critical. Various approaches are being considered to address this problem. One such approach, the application of remotely adjustable on-blade control elements to rotor blades, is receiving considerable attention. This research effort is an attempt to better define the on-blade requirements and ultimately to identify a feasible design implementation.

The objective of this effort, performed by Continuum Dynamics, Inc. under an SBIR (Small Business Innovation Research) Phase I contract, was to determine a mix of on-blade control-surface deflection or in-flight twist change to produce significant payload and range enhancement and blade vortex interaction (BVI) noise reduction for a representative civil tilt rotor. In addition, they were to establish preliminary designs for adjusting blade twist in a rotating environment using smart structures.

Through the combination of a comprehensive analysis and noise prediction code, BVI noise was predicted for various levels of tilt-rotor blade washout (see figure 1). These results demonstrate that if an

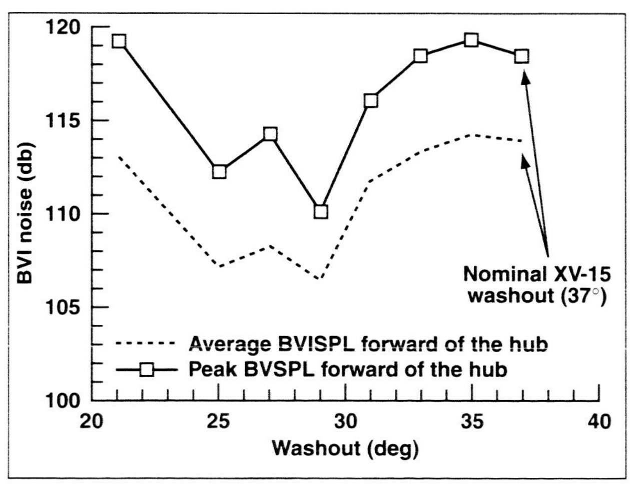

Fig. 1. Effect of blade washout on blade vortex interaction noise.

on-blade device can be developed to decrease blade washout, the BVI noise level in front of the tilt-rotor hub can be reduced by as much as 6 decibels. A noise-reduction strategy combining both on-blade deployment and nacelle tilt could reduce BVI noise levels by as much as 12 decibels. These noise reductions are consistent with NASA's 10- and 20-year goals and, if realized, could significantly accelerate the acceptance of tilt rotors into our national airspace system. In conjunction with this analytical work, various concepts were identified and considered as means to implement the necessary blade twist changes.

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Isolated Tilt-Rotor Aeroacoustics

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As part of the Short Haul Civil Tiltrotor (SHCT) project, an element of the Aviation Systems Capacity program, a test of an isolated tilt rotor was conducted in the Duits-Nederlandse Windtunnel (DNW) open-jet test section in April-May 1998. The model was the isolated configuration of the Tilt-Rotor Aeroacoustic Model (TRAM) and consists of a 0.25-scale V-22 right-hand rotor and nacelle. Aeroacoustic data and rotor wake measurements were acquired for a range of conditions in which blade-vortex interaction (BVI) occurs. The test was led by NASA Ames Research Center in partnership with the U.S. Army, NASA Langley, and the Boeing Company.

Unlike conventional helicopter rotor blades, proprotor blades are highly twisted and can generate negative loading over a large area of the rotor disk. The negative loading causes multiple vortices (of opposite sign) to be shed, thereby increasing the complexity of the wake. Hence, modeling tilt-rotor wakes and predicting tilt-rotor aeroacoustics are very challenging tasks.

The positions of wake segments relative to the rotor blade were acquired for a range of thrust and shaft angles, and the rotation sense of the wake segments was determined. Figure 1 shows a single video frame depicting a counterrotating vortex pair upstream of one of the three TRAM blades. Two-dimensional velocity measurements were also obtained using the particle image velocimetry (PIV) technique. Three methods for averaging the PIV velocity data were investigated with two of the methods accounting for vortex wander. The core size and core circulation of the negative vortices were found to be smaller than the positive circulation vortices. Figure 2 shows the air-loads distribution for the same BVI condition as that shown in figure 1. Note that the blade-tip region is negatively loaded over a substantial region of the advancing side. This kind of loading is much different from that on conventional helicopter blades, where only a small region may be negatively loaded depending on the tip twist. Figure 3 shows the resulting BVI directivity pattern. BVI metric levels were found to increase with rotor-shaft angle for constant advance ratio and rotor thrust coefficient. The maximum BVI levels were found at a much higher shaft angle than would be the case for a typical helicopter.

Data have also been distributed to NASA's SHCT industry partners for enabling an improved understanding and a better prediction of tilt-rotor rotor-noise mechanisms. The isolated TRAM-DNW data will complement the full-span (dual rotors with complete 0.25-scale V-22 airframe representation) TRAM data that will soon be acquired in the Ames National Full-scale Aerodynamics Complex 40- by 80-Foot Wind Tunnel in FY00. By comparing the data from the two tests, an improved understanding of the interactional aerodynamics and acoustics for tilt-rotor aircraft will be achieved.

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